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UNCONFINED COMPRESSIVE STRENGTH OF CEMENT STABILIZED POND ASH

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ABSTRACT

Now a day, ash obtained from thermal power plants can be utilized in the construction of embankments and compacted fills. Ash is a pozzolanic material and its engineering properties can be improved by the addition of cement or lime to it in small quantity. In this study, an effort is made to improve the unconfined compressive strength of Pond Ash deposit by adding cement in it by varying water content in the mix. Ash-Cement mixes were prepared with varying cement content as 3%, 6%, 9%, 12% and 15% for testing unconfined compressive strength. Standard Proctor test was also conducted on the mixes to study Dry density and Optimum moisture content. Results shows that Optimum Moisture Content decreased and Maximum Dry Density increased with increase in cement content in Pond Ash-Cement mixes. The Unconfined Compressive Strength increased with increase in cement content and curing age.

KEYWORDS: Cement, Optimum Moisture, Pozzolanic & Dry Density

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Original Article

INTRODUCTION

Silt-sized coal ash is a cohesion less material having a specific gravity relatively smaller than that of the normal soils. The worldwide production of pond ash is growing every year. Thermal power plants consume a huge amount of coal as a fuel leaving behind residue as coal ash. It requires large land space and difficult to manage hence, causing environmental problems. In situ stabilization methods of the ash deposit to construction sites is a one of the good solutions to manage coal ash. Nowadays, many countries use coal ash to construct embankments and compacted fills. Coal ash is a pozzolanic material and therefore its engineering behavior can be improved by the addition of cement or lime. Ash disposed of in the ponds by the action of water in the ponds is known as POND ASH (PA). It generally contains substantial amounts of silicon dioxide (SiO_2) and calcium oxide (CaO), thus possesses both ceramic and pozzolanic properties. Ash utilization in cement industries and for construction of road / railway embankments after improvement of engineering properties is the solutions to manage the ash.

In this study, the ash samples collected from different radial distance and the depths were tested by varying the water content in the mixes to determine the improvement in dry density, optical moisture content, maximum dry density and unconfined compression strength. A unconfined compressive strength test was done on the mixes having Pond ash mixed with 3%, 6%, 9%, 12% and 15% of cement by weight at curing age of 7, 14 and 28 days.

MATERIALS USED

POND ASH

Pond ash has been used in this study, as it is readily available and has good cementing properties. Pond ash was collected from GURU GOBIND SINGH SUPER THERMAL POWER PLANT (GGSSTP), ROPAR (PUNJAB). The chemical properties were obtained from record office of GURU GOBIND SINGH SUPER THERMAL POWER PLANT (GGSSTP), ROPAR (PUNJAB) are listed in Table-1 and physical properties of the pond ash which were determined in the laboratory are presented in Table-2.

Table 1: Chemical Properties of Pond Ash

Constituents	Ignition loss	SiO_2	AL_2O_3	FeO_2	MgO	CaO
Value (%)	4.52	56.32	30.87	4.94	1.58	0.70

Table 2: Physical Properties of Pond Ash

Parameter	Specific Gravity	Max. Dry Density (kN/m^3)	Optimum Moisture Content (%)	Angle of Int. Friction (ϕ)	Cohesion (kN/m^2)	Permeability (cm/sec)	Coeff. of Uniformity (Cu)	Coeff. of Curvature (Cc)
Value	2.10	11.01	27.4	33°	1	1.24×10^{-4}	8.56	1.41

ORDINARY PORTLAND CEMENT

OPC of 53 grades manufactured by ACC is used in the study. Physical properties of cement are shown in Table-3 and Chemical properties obtained from the record office of ACC Pvt. Ltd. Ludhiana is shown in Table-4.

Table 3: Physical Properties of Cement

Properties	Fineness (m2/kg)	Standard Consistency (%)	Initial Setting Time (min)	Final Setting Time (min)	Specific Gravity	Soundness (mm)	Compressive Strength (MPa)		
							3 days	7 days	28 days
Value	318	34	120	585	3.15	0.5	36.5	43	55

Table 4: Chemical Properties of OPC

Contents	**CaO**	**SiO_2**	**Al_2O_3**	**$CaSO_4$**	**Fe_2O_3**	**MgO**	**S**	**Alkalies**
Range (%)	62-67	17-25	3-8	3-4	3-4	0.1-3	1-3	0.2-1

WATER

Portable water fit for drinking was used throughout the study.

MIX PROPORTIONS

The Pond ash was dried at 105^0 C for 24 hours and then thoroughly mixed with cement in the proportion given in the Table-5

Table 5: Mix Proportions

Mixes	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**
Pond Ash: Cement	97 : 03	94 : 06	91 : 09	88 : 12	85 : 15

TESTING AND RESULTS

Following tests were conducted as per the standard procedure is given in Indian standards.

Standard Proctor Test (Compaction Test)

Standard Proctor test was conducted on mixes having varying proportions of Pond ash and cement. Dry Density of various mixes with different water content is shown in Table-6 and in figures 1.

Table 6: Moisture-Density for Various Mixes

Mixes	Water content (%)					
	15	18	21	24	27	30
M_1	10.86	10.98	11.13	11.32	11.37	11.03
M_2	11.22	11.33	11.48	11.65	11.33	11.03
M_3	11.39	11.61	11.79	11.85	11.46	11.10
M_4	11.53	11.7	11.96	12	11.57	11.26
M_5	11.63	11.78	12.05	12.07	11.88	11.65

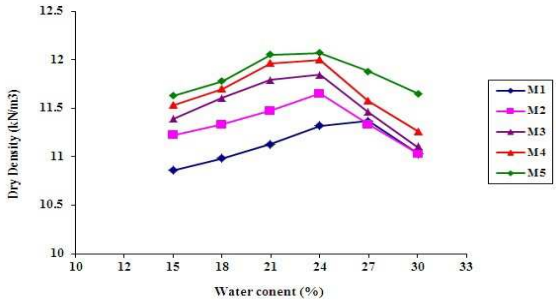

Figure 1: Moisture-Density Relationship for Various Mixes

The values of Maximum Dry Density and Optimum Moisture Content of the mixes are listed in Table-7.

Table 7: Maximum Dry Density & Optimum Moisture Content

Proportion	M_1	M_2	M_3	M_4	M_5
Pond Ash: Cement	97:03	94:06	91:09	88:12	85:15
MDD (gm/cc)	11.39	11.66	11.86	12.02	12.08
OMC (%)	26.00	23.80	23.30	23.00	22.50

It was found that with the increase in cement content, the Maximum Dry density (MDD) increases and the Optimum Moisture Content (OMC) decreases. Therefore, the maximum value of MDD was observed of mix M_5 and maximum OMC was observed of mix M_1.

Unconfined Compressive Strength

As per IS 4332 Part-5, Unconfined compressive strength is one of the best methods to determine the effectiveness of stabilization. Unconfined compressive strength (UCS) test was conducted on the mixes having varying proportions of Pond ash and cement. The test results and stress-strain curves of mix M_1 at curing age of 7, 14 and 28 days were shown in table 8 and figure 9 respectively.

Table 8: UCS of Mix M_1 (Pond Ash: Cement = 97:03)

Reading	Deformation (mm)	At 7 days		At 14 days		At 28 days	
		Strain (%)	Stress (N/mm^2)	Strain (%)	Stress (N/mm^2)	Strain (%)	Stress (N/mm^2)
50	0.5	0.641	0.0480	0.641	0.0556	0.641	0.0708
100	1.0	1.282	0.1207	1.282	0.2012	1.282	0.2565
150	1.5	1.923	0.3448	1.923	0.3748	1.923	0.6996
200	2.0	2.564	0.5237	2.564	0.6454	2.564	0.9060
250	2.5	3.205	0.6905	3.205	0.8138	3.205	1.0850
300	3.0	3.846	0.8231	3.846	0.8819	3.846	1.2983
350	3.5	4.487	0.9247	4.487	1.0707	4.487	1.4114

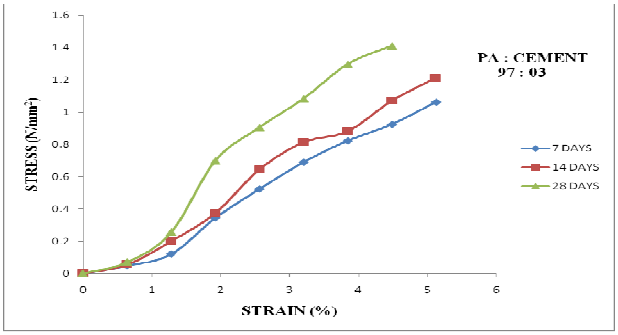

Figure 9: Stress-Strain Curves of Mix M_1 (PA: Cement= 97:03).

The test results and stress-strain curves of mix M_2 at curing age of 7-days, 14-days and 28-days were shown in table 9 and figure 10 respectively.

Table 9: UCS of mix M_2 (Pond Ash: Cement = 94:06)

Reading	Deformation (mm)	At 7 days		At 14 days		At 28 days	
		Strain 0(%)	Stress (N/mm^2)	Strain (%)	Stress (N/mm^2)	Strain (%)	Stress (N/mm^2)
50	0.5	0.641	0.0961	0.641	0.1366	0.641	0.2480
100	1.0	1.282	0.3269	1.282	0.3722	1.282	0.4778
150	1.5	1.923	0.7246	1.923	0.8395	1.923	0.9395
200	2.0	2.564	0.9929	2.564	1.0922	2.564	1.2164
250	2.5	3.205	1.2577	3.205	1.3810	3.205	1.4943
300	3.0	3.846	1.4698	3.846	1.6658	3.846	1.7883
350	3.5	4.487	1.6060	4.487	1.8007	4.102	1.9301

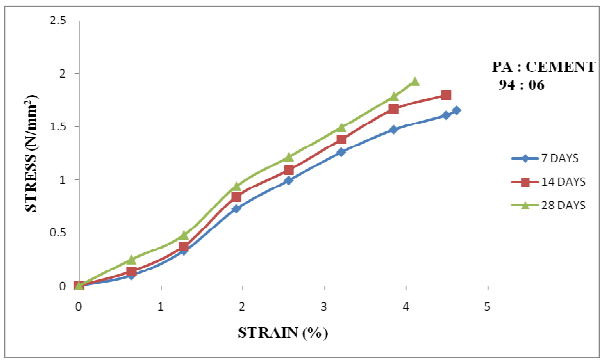

Figure 10: Stress-Strain Curves of Mix M_2 (PA: Cement= 94:06).

The test results and stress-strain curves of mix M_3 at curing age of 7-days, 14-days and 28-days were shown in table 10 and figure 11 respectively.

Table 10: UCS of Mix M_3 (Pond Ash: Cement = 91:09)

Reading	Deformation (mm)	At 7 days		At 14 days		At 28 days	
		Strain (%)	Stress (N/mm^2)	Strain (%)	Stress (N/mm^2)	Strain (%)	Stress (N/mm^2)
50	0.5	0.641	0.2025	0.641	0.2936	0.641	0.3493
100	1.0	1.282	0.4527	1.282	0.5985	1.282	0.6539
150	1.5	1.923	0.8995	1.923	0.9495	1.923	1.0744
200	2.0	2.564	1.2908	2.564	1.390	2.564	1.4894
250	2.5	3.205	1.479	3.205	1.7756	3.205	1.8495
300	3.0	3.846	1.616	3.846	1.9353	3.846	2.0333
350	3.5	4.487	1.727	4.358	1.9737	4.462	2.3114

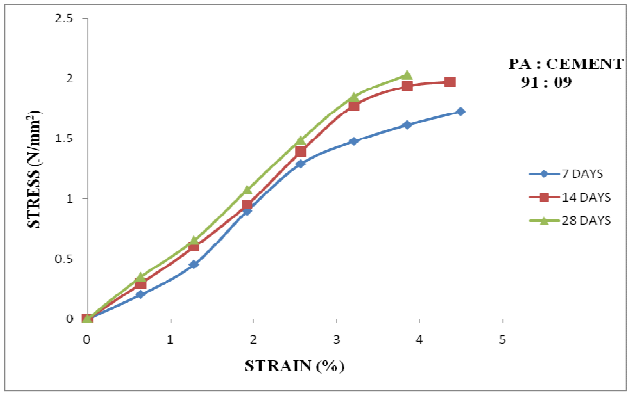

Figure 11: Stress-Strain Curves of Mix M_3 (PA: Cement=91:09).

The test results and stress-strain curves of mix M_4 at curing age of 7-days, 14-days and 28-days were shown in table 11 and figure 12 respectively.

Table 11: UCS of Mix M_4 (Pond Ash: Cement = 88:12)

Reading	Deformation (mm)	At 7 days		At 14 days		At 28 days	
		Strain (%)	Stress (N/mm^2)	Strain (%)	Stress (N/mm^2)	Strain (%)	Stress (N/mm^2)
50	0.5	0.641	0.2582	0.641	0.3341	0.641	0.3999
100	1.0	1.282	0.6036	1.282	0.7444	1.282	0.8551
150	1.5	1.923	1.0994	1.923	1.149	1.923	1.3993
200	2.0	2.564	1.3405	2.564	1.638	2.564	1.7377
250	2.5	3.205	1.5289	3.205	1.898	3.205	2.0222
300	3.0	3.846	1.8128	3.846	2.0088	3.461	2.0906
350	3.5	4.230	1.8446	-	-	-	-

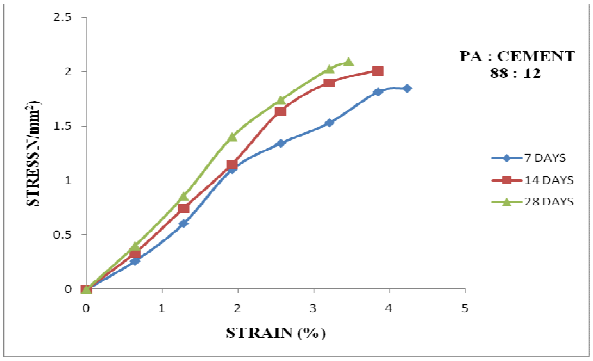

Figure 12: Stress-strain curves of mix M_4 (PA:Cement= 88:12).

The test results and stress-strain curves of mix M_5 at curing age of 7-days, 14-days and 28-days were shown in table 12 and figure 13 respectively.

Table 12: UCS of mix M_5 (Pond Ash: Cement = 85:15)

Reading	Deformation (mm)	At 7 days		At 14 days		At 28 days	
		Strain (%)	Stress (N/mm2)	Strain (%)	Stress (N/mm2)	Strain (%)	Stress (N/mm2)
50	0.5	0.641	0.3037	0.641	0.3999	0.641	0.4202
100	1.0	1.282	0.7293	1.282	0.8299	1.282	0.880
150	1.5	1.923	1.249	1.923	1.3493	1.923	1.449
200	2.0	2.564	1.539	2.564	1.638	2.564	1.886
250	2.5	3.205	1.726	3.205	1.8742	3.205	2.342
300	3.0	3.846	1.910	3.589	2.063	-	-

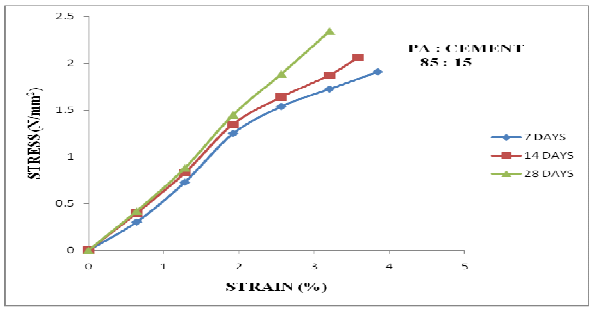

Figure 13: Stress-Strain Curves of Mix M_5 (PA: Cement= 85:15)

The Stress-Strain behavior of Pond Ash: Cement mixes show gains in compressive strength with increase in the time period. Unconfined compressive strength results of all the mixes having different proportions of Pond ash and Cement content are presented in table 14.

Table 14: UCS of Mixes Having Different Proportions of Pond Ash and Cement

Mix	PA: Cement (%)	UCS in N/mm^2		
		7 days Curing	14 days Curing	28 days Curing
M_1	97:03	1.064	1.212	1.411
M_2	94:06	1.653	1.801	1.930
M_3	91:09	1.727	1.974	2.033
M_4	88:12	1.845	2.009	2.091
M_5	85:15	1.910	1.990	2.342
M_6	82:18	2.071	2.225	2.532

The Unconfined Compressive Strength (UCS) of mixes increases with the increase of cement content and the curing period. A maximum value of UCS is found in the mix M6 at 28 days of curing.

CONCLUSIONS

On the basis of the investigation, the following conclusions have been drawn:

- In case of POND ASH: CEMENT mix, Optimum Moisture Content (OMC) decreased and Maximum Dry Density increased with increase in cement content in the PA-Cement mix. A maximum value of OMC was observed at mix M_1 (PA:CEMENT= 97: 03) and of MDD was observed at mix M_6
- It was seen that with an increase in cement content in the PA-Cement mix, the Unconfined Compressive Strength increased and its maximum value was obtained at 28 days of curing for the mix M_6 (PA:CEMENT = 82: 18).
- It was seen that curing period also had an impact on strength improvement in the present study. Maximum values of compressive strength were achieved at 28 days of curing age for all the mixes.

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